EP271 Heat, Kinetic Theory, and Thermodynamics
Final Examination

Department of Physics and Engineering Physics, University of Saskatchewan
Instructor: Alex Plyuhkin

April 19, 2005, Time: 2:00 pm-5:00 pm

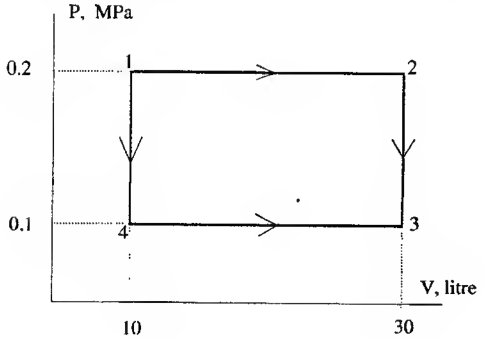
Textbooks and notes are not allowed. You can use two pages formula sheet.
Each set of questions has the same weight.

Set 1:

1.1. Formulate the first law of thermodynamics

1.2. The internal energy of a gas depends on temperature and pressure as $U = a\ln(T/T_0) + b\ln(P/P_0)$, where a, b, T_0, P_0 are constants. Receiving the amount of heat Q, the gas is heated from temperature T_1 to temperature T_2 and does the work W. Find the ratio P_2/P_1 of pressure in the final and initial states.

1.3. A body (not necessarily an ideal gas) passes from state 1 to state 3 one time by means of the process $1 \rightarrow 2 \rightarrow 3$ and another by means of the process $1 \rightarrow 4 \rightarrow 3$. Using the data indicated in the figure below, find
a) the difference $\Delta Q = Q_{123} - Q_{143}$ between the amount of heat received by the body during two processes.
b) the corresponding differences for internal energy and entropy, ΔU and ΔS.
(Note $1MPa = 10^6 Pa$, $1\,L = 10^{-3}\,m^3$)



Set 2 :

2.1. Give the relationship between heat capacities C_P and C_V. Give quantitative explanation why $C_P > C_V$.

2.2. Two moles of diatomic ideal gas is confined to a container at atmospheric pressure and temperature $T = 273\,K$. How much heat energy is needed to double the pressure of the gas?

2.3. Find molar specific heat of an ideal gas as a function of volume, $c(V)$, for the process $P = aT^\alpha$. a and α are constants. Specific heat for constant volume, c_V, is supposed to be known.

Set 3:

3.1.

a) What is the efficiency of a heat engine?

b) Give formulation(s) of the second law of thermodynamics making reference to a heat engine

3.2. In the course of a Carnot cycle, the working substance receives the heat $Q_h = 300\,kJ$ from a high temperature bath. The temperatures of the high and low temperature baths are $T_h = 450\,k$ and $T_c = 280\,K$, respectively. Find the work W done by the working substance during the cycle.

3.3.

a) Find the work done by an ideal gas (with given $\gamma = c_p/c_v$) in expanding adiabatically from a state (p_1, V_1) to a state (p_2, V_2).

b) Find the net work along two adiabats of the Carnot cycle.

Set 4:

4.1. What arguments you may suggest to support the statement that thermodynamic entropy is a function of state?

4.2. An ideal gas is confined to a cylinder by a piston. The piston is slowly pushed in so that the gas temperature remain at $20°\ C$. During the compression, $730J$ of work is done on the gas. Find the entropy change of the gas.

4.3. An ideal gas with given $\gamma = c_p/c_v$ performs a two-step process $1 \to 2 \to 3$. The initial volume and pressure P_1, V_1, as well as the volume of the final state V_3, are given. About the intermediate state 2 it is known only that the entropy change ΔS_{12} for the first step $1 \to 2$ and ΔS_{23} for the second step differ only by sign, $\Delta S_{12} = -|\Delta S_{23}|$. Find pressure in the final state, P_3.

Set 5:

5.1. How entropy is defined in kinetic theory? Based on this definition, explain shortly how the entropy increase in irreversible processes can be interpreted in kinetic theory.

5.2. The average energy of the molecules of a diatomic ideal gas $\langle \epsilon \rangle = 5 \times 10^{-21}\,J$. The pressure of the gas is $P = 2 \times 10^5\,Pa$. Find the concentration of molecules (the number of molecules in a unit volume).

5.3. An ideal gas of rigid diatomic molecules ($\gamma = 7/5$) expands adiabatically. Given the ratio of the initial and final volumes $\alpha = V_i/V_f$ and the initial temperature T_i, find the average kinetic energy of rotational motion of a molecule in the final state.